

Chapter 15

Parametric Evaluation of Leachate Generated from a Non-engineered Landfill Site and Its Contamination Potential of Surrounding Soil and Water Bodies



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Abstract Open dumping of municipal solid waste causes environmental degradation including air, soil and groundwater pollution leading to adverse impact on public health. The present study provides the physico-chemical characterization of groundwater, leachate and surface water being affected by the percolation of leachate into aquifers in the study region Solan, Himachal Pradesh. Testing was carried out in two seasons (monsoon season and winter season) to study the effect of leachate contamination on the groundwater. The physico-chemical characterization of groundwater study observed the pH value of groundwater 7.41 in monsoon season and 8.2 in winter season that varied from slightly neutral to alkaline. The total dissolved solids were observed 242 mg/L in monsoon season and 250 mg/L in winter season. The value of sulfate was evaluated as 63 mg/L in monsoon season and 68 mg/L in winter season whereas nitrate, ammoniacal nitrogen, biological oxygen demand and chemical oxygen demand has been found

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below the detection level. However, the biological oxygen demand and chemical oxygen demand of surface water was found 6.2 and 20 mg/L in monsoon season whereas 6.0 and 22 mg/L in winter season, respectively. The national foundation sanitation method was applied to determine the water quality index in Solan region. It revealed the poor quality of water due to the open dumping, and thus percolation of leachate into the groundwater.

Keywords Groundwater · Heavy metal · Leachate · Water quality index
Soil contamination

15.1 Introduction

Rapid growth in urbanization and industrialization has led to severe environmental degradation including increased generation of solid waste (Puri et al. 2008; Sethi et al. 2013). In particular, solid waste management has always been a pertinent issue for developing countries (Shekdar 2009). This is primarily due to poor waste management practices including lack of authentic data and information to assess the existing management systems (Chang and Davila 2008; Hancs et al. 2008). The increased rate in the population of Indian cities is one of the major contributors to the generation of municipal solid waste. Further, the enhanced rate of migration of people from rural to the urban areas has led to overwhelming demographic growth in many cities through worldwide. The increased rate of production and consumption of synthetic products and services is generating a bulk quantity of solid waste in cities. Municipal solid wastes are hence produced from municipal services including dead animals waste, vegetable market wastes, municipal wastes, commercial wastes and institutional wastes (Sharma et al. 2018). The rapid growth of municipal solid waste depends upon the living standards of people and consumption pattern of goods by the residents. The population of India has also rapidly migrated from agricultural-based nation to the urbanization and industrialization. Urban areas in India generates about 48 million tonne of municipal solid waste annually whereas per capita national MSW generation ranges between 200 and 600 gm. The three mega cities in India including Greater Mumbai, Kolkata and Delhi having a population of more than 10 million, 53 cities have more than 1.0 million populations and 415 cities having population 100,000 (CPCB 2013). This has led to further increased growth of municipal solid waste (MSW) generated in urban areas. The population growth in India between 1911 and 2011 has been shown in Table 15.1.

The current scenario of municipal solid waste management in Indian cities is not very satisfactory. It is reported that municipal solid waste generated in India is 127,486 tonne per day and 47 million tonne per year as per the status of CPCB 2013. Out of the total solid waste generated in India, 89,334 tonne (70%) is collected, 15,881 tonne (12.50%) is being treated while 22,271 tonne (17.5%) is not being collected. Increasing industrialization and rising income levels lead to greater use of resources which further leads to the increased MSW generation and more

Table 15.1 Population growth in India between 1911 and 2011 (CPCB 2013)

Census year	Population	Average annual exponential rate (%)	Population growth rate compared with 1911 (%)
1911	252.0	0.56	5.76
1921	251.3	-0.03	5.42
1931	278.9	1.04	17.02
1941	318.6	1.33	33.67
1951	361.6	1.25	51.47
1961	439.2	1.96	84.25
1971	548.1	2.20	129.94
1981	683.3	2.22	186.64
1991	846.4	2.16	255.05
2001	1028.7	1.97	331.52
2011	1210.2	1.64	407.62

Table 15.2 Estimated waste generation in Himachal Pradesh (Sharma et al. 2018)

Year	Per capita waste generation	Urban population	Waste generated (tonne/day)
2011	0.413	736.33	304.3
2021	0.472	883.32	416.6
2031	0.538	1023.42	550.9
2041	0.614	1155.249	709.6

complex composition of MSW than earlier the generation of municipal solid waste in Himachal Pradesh was estimated to be 350 tonne per day in the year 2015 (Sharma et al. 2018). The estimated waste generation in the municipal solid waste in Himachal Pradesh has been shown in Table 15.2.

In low-income countries like India, the waste collected from the cities are often not segregated. The mixed form solid waste leads to generation of cocktail of different toxic chemicals producing leachate which often pass through the soil thereby contaminating the surrounding soil and groundwater sources and other potential environmental consequences (Mor et al. 2006; Kaushik and Sethi 2007a, b). The problem of environmental contamination has severely increased due to open dumping of the wastes in non-engineered landfill sites. Further, almost 90% of the solid waste generated from major cities and town in India is open dumped as it is a highly cost-effective method (Hazra and Goel 2009; Rana et al. 2015). It is estimated that 950 million tonne of municipal solid waste is generated on an annual basis because of various human activities including municipal, agricultural and industrial activities in India. Of the total waste generated, 350 million tonne of solid waste is organic waste. Inorganic waste accounts for 290 million tonne from industrial activities and 5 million tonne is a hazardous waste (Kumar and Alappat 2005). Further, the per capita generation of municipal solid waste varies within the range of 0.20–0.87 kg/capita/day with the significantly higher values in urban areas in comparison to rural areas (Hazra and Goel 2009; Rana et al. 2015).

Rainwater coming in contact with the municipal solid waste generally dissolves the organic fraction of the MSW. The resulting liquid effluent has a complex brown colour and is known as leachate (Mor et al. 2006; Bhalla et al. 2012). Leachate thus generated from the degradation of municipal solid waste in the open dumps can migrate to the aquifers, thereby polluting groundwater and soil in the periphery of the dumping ground rendering them unsuitable for any of the domestic or commercial use (Mor et al. 2006; Manaf et al. 2009; Pillai et al. 2014). Further, the closure of such disposal sites still has the potential to produce leachate for many years and can degrade the surrounding environment (Nagarajan et al. 2012; OgunDIRAN and Afolabi 2008).

The impact of leachate on contamination of groundwater has been reported in many studies indicating the presence of high concentrations of both organic and inorganic material cause pollution to environment due to percolation of leachate (Longe and Balogun 2010; Akinbile and Yusoff 2011; Parameswari et al. 2015). The various factors on which the composition of the leachate depends on landfill age, rainfall intensity as well as the amount of municipal solid waste and decomposition of waste (Shivasharanappa and Huggi 2011). To summarize, leachate is a significant source of environmental problems. Therefore, the physico-chemical characterization and assessment of heavy metal in leachate and its potential contamination of surrounding water bodies that are affected by leachate is of significant concern. The potential contamination of water sources by leachate is described by water quality index method reported in earlier studies (Swamee and Tyagi 2000). Aggregate index is the technique that has a tendency to decrease with the incremental of time due to the degradation of municipal solid waste whereas also increases when increased the distance from the respective dumpsite (Sharma et al. 2016; Swamee and Tyagi 2007). The contamination of the soil by leachate in principle generally alters the engineering properties of soil including its shear strength and CBR properties. This is because, with the decay in the organic fraction of the MSW, they react with the existing soil fraction leading to change in soil properties. This is particularly important if the dumpsite is to be reused for constructing purposes after the design period of dumpsite. In such conditions, the engineering properties are most predominant in determining the reusability of such dumpsites. The purpose of the present study is to analyze the physico-chemical characterization of leachate, groundwater, surface water and soil quality that is being affected by percolation of leachate into aquifers in non-engineered dumping sites. However, the toxicity level of the leachate on groundwater has been presented in single term known as an aggregate index.

15.2 Site Location

Solan region lies within the Universal Transverse Mercator coordinates of (700384.18, 3420901.86) in the zone of 43R. The waste generation rate is estimated in the range of 21–22 tonne per day (TPD) and the per capita waste generation is

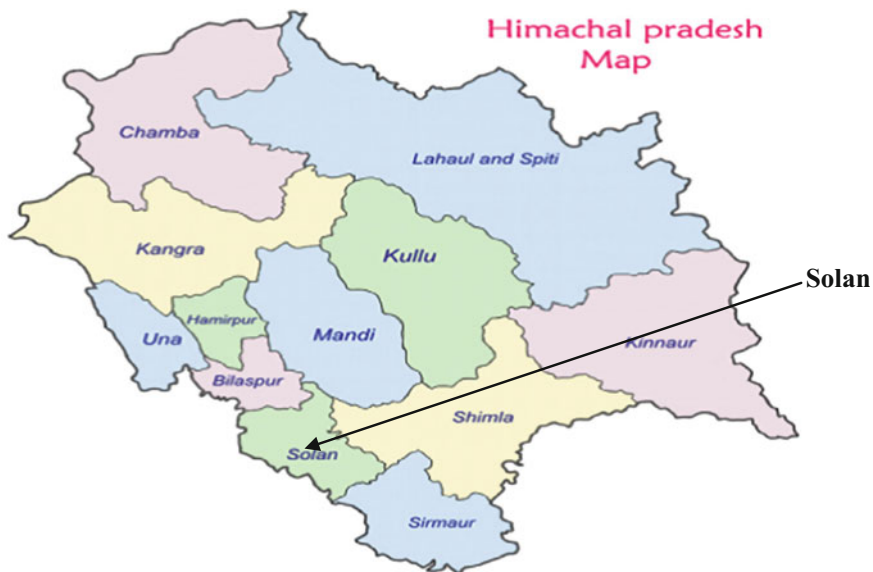


Fig. 15.1 Location of the study area in Himachal Pradesh

0.42 kg per person per day in the study region (Sharma et al. 2018). The collection efficiency of the region was observed around 60% that is not satisfactory for the proper waste management system. The location of the study area has been shown in Fig. 15.1.

The MSW dumpsite in Solan city is located in Salogra and experiences about 18.5–20 tonne per day of waste. The collection efficiency of the waste in the study location is 60% with a high fraction of organic waste being dumped at the Salogra location. Along with the waste collected from different households, the vegetable vendors also dispose of rotten fruits and vegetables at the Salogra dumpsite leading to an increased fraction of organics in the waste. The dumpsite is an open dumpsite and is non-engineered landfill site.

15.3 Methodology

The section has been explained in the following sub-headings as follows:

15.3.1 Collection of Samples

The leachate samples were collected from the downstream section of the municipal solid waste dump site in Salogra in Solan region whereas the groundwater samples were collected from hand pumps near the periphery of the dumping site. All the samples were collected for two seasons, i.e. monsoon season and winter seasons to evaluate the seasonal variation on the quality of groundwater. The samples were collected in tight plastic bottles for the evaluation studies. The water and leachate samples were then transported to the laboratory and analysed for physico-chemical and heavy metal parameters within 2 days according to the standard procedures (Parameswari et al. 2015).

Experimental investigations were performed as per APHA 22nd Edition 2012 for analyses of pH, Turbidity, Total Dissolve Solid (TDS), Chloride, nitrate, sulfate, trace metals, bacteriological parameters, biological oxygen demand (BOD), and chemical oxygen demand (COD). The pH of the samples was also measured to site with the help of pH strip. The turbidity of sample solution can be measured by using Nephelometer. It is usually measured in Nephelometric turbidity units (NTU). The heavy metal content of water and leachate were determined using an atomic absorption spectrophotometer (AAS). The working principle of the AAS basically involves the utilization of free atoms (gas) that are generated from the atomizer absorbing the radiation generated at that particular frequency.

15.3.2 Aggregate Index Method

Aggregate index or water quality index method was applied to evaluate the quality of groundwater collected within the periphery of dumping site. The water quality index method utilized for determining the quality of the water was based on the method as proposed by National Sanitation Foundation (Swamee and Tyagi 2000, 2007) to evaluate the toxicity potential of leachate into the groundwater. In particular, the study includes how indices are calculated and how they are used in determining water quality index using National Sanitation Foundation work.

15.3.2.1 Water Quality Index (NSF Method)

The sub-index of different water quality variables (surface water and groundwater) has been determined by the National Sanitation Foundation method to evaluate the water quality index. The method including a selection of parameters and assigned weightage to each parameter based on its importance and the parameters including pH, turbidity, total dissolved solids, and biochemical oxygen demand was introduced. Thereafter, the data were recorded and then transfer to a weighting curve chart, where a numerical value of Q_i is obtained. The mathematical expression for national sanitation foundation (WQI) is given below:

$$WQI = \sum_{i=1}^n Q_i W_i$$

Q_i i th water quality parameter for sub-index

W_i weight assigned with i th water quality parameter

n number of water quality parameters.

15.4 Results and Discussions

15.4.1 Leachate Analysis

Laboratory tests were performed for the analysis of leachate. For this purpose, different parameters were analysed like; pH, TDS, nitrate, sulfate, heavy metals, BOD, COD, and bacteriological analysis for leachate samples. The physico-chemical characteristics of leachate samples have been shown in Table 15.3.

The pH value observed for leachate sample was found 7.4 in monsoon season (September 2015) and 7.8 in the winter season (February 2015) whereas the concentration of TDS was observed high for both the monsoon season and winter season, i.e. 968 and 2000 mg/L respectively. The COD for leachate sample was observed 7150 and 7200 mg/L that clearly indicates the presence of higher amount of inorganic matter in the municipal solid waste. The BOD in leachate sample was also reported very high for both the seasons, i.e. 2300 and 2410 mg/L. The concentration of sulfate of leachate sample was observed 50 and 48 mg/L for both the seasons including monsoon season and winter season. These values have been found lesser than the values observed from earlier works as reported by Pillai et al. (2014) whereas the concentration of sodium (1400–8000 mg/L) and chloride (900–11,500 g/L) were reported higher for both the seasons. Apart from this, the

Table 15.3 Physico-chemical parameters of leachate samples

S. No.	Parameters	Results (September 2015)	Results (February 2016)
1.	Conductivity (μ mhos/cm)	2960	2880
2.	pH	7.4	7.8
3.	TDS (mg/L)	1968	2000
4.	Sulfate (mg/L)	50	48
5.	Nitrate (mg/L)	27	28
6.	Ammoniacal nitrogen (mg/L)	Nil	5
7.	BOD at 27 °C 3 day (mg/L)	2300	2410
8.	COD (mg/L)	7150	7200

Table 15.4 Testing results of leachate samples for heavy metal

S. No.	Parameters	Values (mg/L) (September 2015)	Values (mg/L) (February 2016)
1.	Lead	0.0351	0.04
2.	Zinc	0.0838	0.078
3.	Chromium	BDL	BDL
4.	Nickel	0.0168	0.0189
5.	Iron	0.21	0.28

groundwater showed higher values of total dissolved solids ranged between 470–2990 mg/L during post-monsoon and 120–2800 mg/L during pre-monsoon, whereas chloride content ranged between 140–1500 mg/L during post-monsoon and 120–2800 mg/L during pre-monsoon. The BOD and COD of the groundwater were found nil for monsoon season and winter season, respectively. The concentration of parameters for leachate sample including calcium, magnesium, nitrate, and TDS were observed on the higher side than the prescribed limits. The study clearly indicated that most of the parameters have been found exceeding their permissible limits. Moreover, the results revealed were found greater than the earlier works as reported in the literature (Parameswari et al. 2015).

The heavy metal concentration of leachate samples has been listed in Table 15.4. The results revealed that the concentration of lead content was higher than permissible limits for the leachate sample, i.e. 0.0351 mg/L that may cause problems such as brain damage, kidney failure, etc. The concentration of zinc content in leachate has been found 0.0838, 0.078 mg/L for both the seasons. The concentration of Zn was found within the permissible limits (0.264 and 0.947 mg/L) of the World Health Organization for all samples whereas the concentration of chromium in leachate was found below the detection limit. The COD was also reported high 518.14 and 725.01 mg/L.

15.4.2 Groundwater and Surface Water Analysis

Laboratory tests were performed for determining the effect of decomposition of solid waste and percolation of on groundwater quality. For this purpose, different parameters were analysed like pH, total dissolved solids, nitrate, sulfate, heavy metals, BOD, and COD testing for surface water and groundwater. Table 15.5 shows testing of surface and groundwater samples for physico-chemical parameters and comparison with WHO standards.

The turbidity for surface water and groundwater was determined to be 7 and 40 NTU, respectively for samples collected during September 2015. However, it was determined to be 8 and 42 NTU for samples obtained in February 2016. This shows that turbidity of groundwater was significantly higher than surface water

Table 15.5 Physico-chemical analysis of surface water and groundwater samples

S. No	Parameters	Result (surface water) September 2015	Results (surface water) February 2016	Results (groundwater) September 2015	Results (groundwater) February 2016	Acceptable limits (WHO)	Permissible limits (WHO)
1.	Turbidity (NTU)	7	8	40	42	-	-
2.	EC (micro mhos/cm at 25 °C)	598	616	372	385	-	-
3.	pH	8.28	8	7.41	8.2	6.5-8.5	No relaxation
4.	TDS (mg/L)	389	400	242	250	500	2000
5.	Sulfate (mg/L)	18	20	63	68	200	400
6.	Nitrate (mg/L)	0.15	0.2	BDL	BDL	45	No relaxation
7.	Ammoniacal nitrogen (mg/L)	Nil	Nil	Nil	Nil	-	-
8.	BOD (mg/L)		6.0	Nil	Nil	-	30 (surface water)
9.	COD (mg/L)	20	22	Nil	Nil	-	250 (surface water)

Table 15.6 Heavy metal analysis of surface water and groundwater comparison with WHO standards

Parameters	Surface water (September 2015)	Groundwater (September 2015)	Surface water (February 2016)	Groundwater (February 2016)	Acceptable limits (WHO)	Permissible limits (WHO)
Lead (mg/L)	0.0241	0.0271	0.0271	0.025	0.01	No relaxation
Zinc (mg/L)	0.0137	0.0178	0.014	0.02	5	15
Chromium (mg/L)	BDL	BDL	BDL	BDL	0.05	No relaxation
Nickel (mg/L)	0.0056	0.0024	0.008	0.0028	0.02	No relaxation

sources for both the seasons but illustrates no marked difference for intra-source comparisons. pH values observed for the entire monitoring campaign were within 'near-neutral ranges', and hence were suitable for disposal purposes. Similarly, TDS and sulfate concentrations were well within the permissible ranges prescribed by WHO. No BOD and COD concentrations were reported for groundwater sources over the two monitoring seasons and the concentrations obtained for surface water sources were well within the permissible limits. These reported results were lesser than earlier values reported in the literature (Akinbile and Yusoff 2011). The results clearly indicate that some of the parameters show the amount of traceable pollution level but are below the World Health Organization (WHO) and the National Standard for Drinking water quality (NSDWQ) limits. The results of heavy metals for surface water and groundwater was shown in Table 15.6.

The major heavy metals obtained in the analysis of the collected samples revealed concentrations lead, zinc, chromium, and nickel. It was observed that the lead concentrations from both surface and groundwater exceeded the acceptable limits prescribed by WHO (Parameswari et al. 2015). Zinc and Nickel concentrations were well within or below the prescribed limits. Chromium concentrations were undetectable being less than the least count of the instrument. Biological examination of the collected samples was carried out and the analysis revealed that biological contamination was absent in both water samples.

15.4.3 Water Quality Index

Groundwater is highly susceptible to pollution by leachate. The degree of pollution depends on number of factors including the toxicity potential of leachate, the underlying soil strata which determines the hydraulic gradient of the permeability of

the leachate, the depth of water table and the direction of flow of groundwater. These conditions primarily determine the seepage of leachate and contamination of groundwater.

Water quality index is an effective approach for the prediction of water quality that is found helpful for the selection of allocated and effective treatment processes. In this context, it is depicted that the indices utilized in the aggregate indexing are based on the different types of water quality parameters depending upon the importance of each individual parameter and their comparison with the standards. The water quality indexing or aggregate indexing has been determined by National Sanitation Foundation (NSF) Method based on the different physico-chemical parameters utilized for the study purpose including pH, BOD, turbidity, and total solids.

Calculation of Sub-indices The sub-indices of different water quality parameters for surface water and groundwater were determined based on water quality index method named National Sanitation Foundation of weighting curve chart given by (NSF) as given in Tables 15.7 and 15.8. The gradation of water quality index was listed in Table 15.9. After the calculation of sub-indices of groundwater and surface water for both seasons (monsoon and winter) in September 2015 and February 2016, respectively, water quality index has been determined to analyze the quality of surface water and groundwater. The water quality was measured on the scale of 0–100 and the quality of water varies in the range of very bad to excellent.

The water quality index based on National sanitation foundation (NSF) of various sub-indices for different parameters of surface water and groundwater are shown in Tables 15.10 and 15.11, respectively

The weightage to different quality variables were given based on National Sanitation Foundation method (NSF) of water quality index. The product of

Table 15.7 Sub-indices of surface water quality variables (NSF)

S. No.	Parameters	Surface water (September 2015)	Sub-index (S)	Surface water (February 2016)	Sub-index (S)
1.	Turbidity	7	81	8	79
2.	EC (micro mhos/cm at 25 °C)	598	–	616	
3.	pH	8.28	83	8	87
4.	TDS (mg/L)	389	49	400	48
5.	Sulfate (mg/L)	18	–	20	–
6.	Nitrate (mg/L)	0.15	–	0.2	–
7.	Ammoniacal nitrogen (mg/L)	Nil	–	Nil	–
8.	BOD at 27 day (mg/L)	6.2	49	6.0	50
9.	COD (mg/L)	20	–	22	–

Table 15.8 Sub-indices of ground water quality variables (NSF)

Parameters	Ground water (September 2015)	Sub-index (S)	Ground water (February 2016)	Sub-index (S)
Turbidity (NTU)	40	44	42	42
EC (micro mhos/cm at 25 °C)	372	–	385	
pH	7.41	94	8.2	82
TDS (mg/L)	242	69	250	67
Sulfate (mg/L)	63	–	68	–
Nitrate (mg/L)	BDL	–	BDL	–
Ammoniacal nitrogen (mg/L)	Nil	–	Nil	–
BOD at 27 °C (mg/L) 3 day(mg/l)	Nil	0	Nil	0
COD (mg/L)	Nil	–	Nil	–

Table 15.9 Water quality index table (NSF)

S. No.	Range	Quality of water
1.	0–25	Very bad
2.	26–50	Bad
3.	51–70	Medium
4.	71–90	Good
5.	91–100	Excellent

Table 15.10 Water quality index of surface water quality variables (NSF)

Parameters	Sub-indices (September 2015) S_i	Weight age w_i	$S_i \times w_i$	Sub-indices (February 2016) S_i	Weight age w_i	$S_i \times w_i$
Turbidity (NTU)	81	0.25	20.25	79	0.25	19.75
pH	83	0.315	26.15	87	0.315	27.40
BOD (mg/L)	49	0.26	12.74	50	0.26	13
TDS (mg/L)	49	0.25	12.25	48	0.25	12

sub-index and weightage has been calculated and the summation of product and weight of these calculated sub-indices has been determined. The summation of surface water and weight of surface water in the year September 2015 was 71.39 and in the year February 2016, it was 72.15. The water quality lies in the range of 71–90 which indicated the good quality of water and the impact of leachate on surface water was not significant as yet. As in the case of groundwater quality,

Table 15.11 Water quality index of groundwater quality variables (NSF)

Parameters	Sub-indices (September 2015) S_i	Weight age w_i	$S_i \times w_i$	Sub-indices (February 2016) S_i	Weight age w_i	$S_i \times w_i$
Turbidity (NTU)	44	0.25	11.0	42	0.25	10.50
pH	94	0.315	29.61	82	0.315	25.83
BOD (mg/L)	0	0.26	0	0	0.26	0
TDS (mg/L)	69	0.25	17.25	67	0.25	16.75

quality index in the initial year was 57.86 and in the final year 2016, it was 53.08. This lies in the medium quality range 51–70 that indicated some minor contamination of groundwater, and if unchecked could deteriorate further due to seepage of leachate in the groundwater.

15.4.4 Soil Pollution

The physico-chemical and heavy metals analysis of soil samples in the vicinity of the dumpsite were carried out for possible contamination and are shown in Tables 15.12 and 15.13, respectively.

The observed value of pH for the soil sample was slightly acidic because organic acids are formed by the degradation of the organic matter. Apart from this, sodium, sulfate, chloride, and nitrate content were observed 760, 20.63, 960, and 103.55 mg/L. This higher concentration of parameters was mainly due to improper disposal of solid waste and percolation of leachate into soil causing adverse effects to the soil. These results were compared to those as reported in the text showing similar contamination levels (Ogundiran and Afolabi 2008; Akinbile and Yusoff 2011).

Table 15.12 Testing results of physico-chemical parameters for soil samples

S. No.	Parameters	Results (September 2015)	Results (February 2016)
1	pH	7.9	7.11
2	Conductivity (micro mhos/cm at 25 °C)	600	560
3	Sulfate (mg/kg)	345	325
4	Nitrate (mg/kg)	17	15
5	Ammoniacal nitrogen (mg/kg)	18	16

Table 15.13 Testing results of heavy metal parameters for soil samples

S. No.	Parameters	Heavy metals (mg/kg) (September 2015)	Heavy metals (mg/kg) (February 2016)
1	Iron	1.2	1.4
2	Nickel	0.428	0.440
3	Lead	2.908	3.0
4	Chromium	0.050	0.070
5	Zinc	1.850	1.860

From Table 15.13, it is observed that heavy metals in soil sample included iron, nickel, chromium, and zinc has been found 1.2, 0.426, 0.050, and 1.850 mg/kg in monsoon season and 1.4, 0.440, 0.070, and 1.860 mg/kg in winter season, respectively. The value for lead was found on the higher side it was 2.908 mg/kg in September 2015 and 3.0 mg/kg in February 2016. pH is a key factor which affects the leaching of the metals from upper soil profile to lower. If the pH is low, it will accelerate the migration of metal from upper to lower soil profile. In municipal solid waste dump sites, pH depends upon anaerobic decomposition of waste. More anaerobic decomposition means more acid will produce, it will decrease the pH and in acidic condition, metal will move from upper to lower soil profile.

15.5 Conclusions

Leachate causes soil and water contamination as it percolates through the soil strata. The present study reports the possible water and soil pollution due to leachate generated at an open dumpsite in Salogra (Solan District) in Himachal Pradesh from samples collected over two seasons. Parameters tested for leachate samples show very high concentrations of certain physico-chemical parameters leading to increased toxicity of the leachate generated. Heavy metals concentration was significantly in lesser concentrations. The water quality index assessment carried out shows that the surface water quality was good and thereby had not been affected by the leachate contamination but groundwater quality was classified as relatively medium suggesting some probable contamination. Further, there is a possibility of further contamination of groundwater due to the process of continued dumping of waste. Determination of soil characteristics showed that not much adverse effect has happened yet at the dumpsite but with continued dumping of waste at the site, possibility exists of increased contamination at the dumpsite. Hence, for the prevention of leachate percolation into the aquifer, the trend of open dumping should be restricted and properly engineered landfill facility should be made with liner and leachate collection system for the safe discharge of leachate.

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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